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Mosquitoes and West Nile Virus

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Introduction

West Nile virus (WNV) is a mosquito-transmitted disease that was first detected in the United States in 1999 in the New York City area. It has been known from parts of Africa, southern Europe, the Middle East and Asia for several decades and was probably introduced into the U.S. via an infected bird, mosquito or human traveler. Currently the disease has been reported in nearly every state east of the Rocky Mountains plus California, and it will likely be present in the entire continental U.S. within a few years. In Michigan, the virus has already been found in most counties and is expected to be confirmed in all by next year.

WNV is principally a disease of birds, but other animals and humans can become infected. Horses can contract the disease and it may become fatal in these animals. In humans, the disease is serious mainly for the elderly, but people in all age groups can be infected and can become seriously ill. Human cases were first reported in Michigan in 2002, and at least 35 deaths were confirmed among over 400 hospitalized people. Symptoms can range from none to those associated with flu (fever, headaches, joint aches, weariness) to those characteristic of severe encephalitis (high fever, disorientation, brain swelling, paralysis, etc.). Most people who contract the virus develop an effective immune response and show no or minor symptoms. Some individuals, however, are more susceptible to the virus and the resulting disease can be fatal in rare instances.

WNV can infect many species of animals, but there is little current evidence to suggest that the disease is widespread or serious in any group other than humans, horses and birds. White-tailed deer, for example, can become infected without serious consequences. The risk to hunters who dress their deer is low because of minimal virus levels in deer blood. Hunters might consider wearing gloves when dressing the carcass and definitely avoid blood-to-blood contact via an open wound. Bats, squirrels, rats and other animals have tested positive for WNV, but again, there is no evidence to suggest they are susceptible to, or consistent reservoirs of, the virus. Dogs and cats can contract the disease, but only one dog in the United States is thought to have died from the disease. WNV fatalities in the United States have been reported for more than 100 species of resident and migratory birds (see WNV site at www.cdc.gov). Owners of exotic pet birds should be aware that WNV is a serious concern for these animals. However, domestic fowl, such as chickens, do not appear to be susceptible.

Counties in Michigan are considered positive for WNV if its presence is confirmed in at least one dead bird found in the county. Dead birds may be report-

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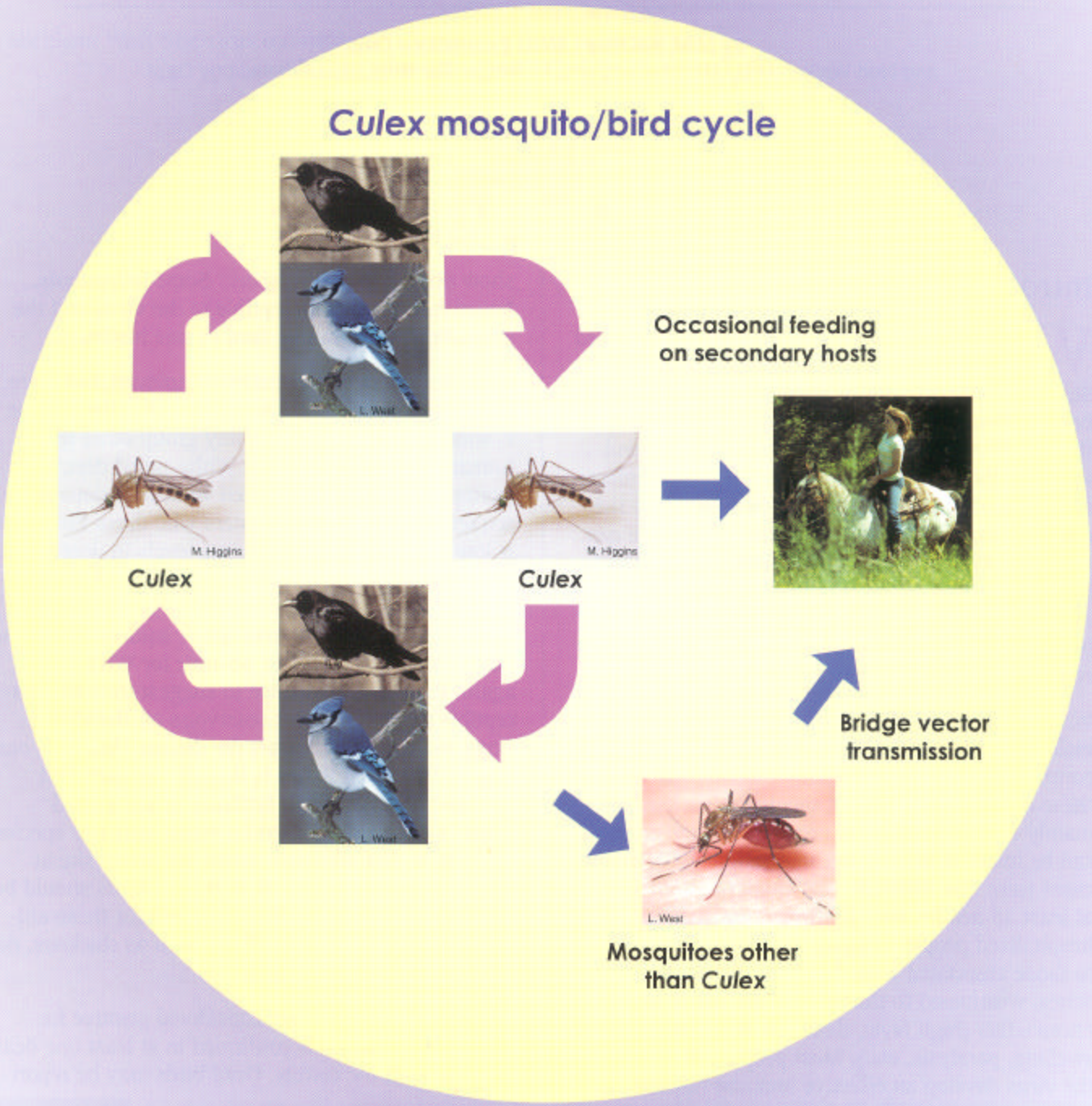
West Nile Virus Transmission Cycle



ed to the Michigan Department of Agriculture (888-668-0869) or the Diagnostic Center for Population and Animal Health at the MSU College of Veterinary Medicine (517-353-2296, <www.maders.msu.edu/m5/Default.asp>). You will be advised if they need to be sent in for testing. Dispose of dead birds as you would any other refuse. Birds often carry other diseases, so it is advisable to wear gloves and place the birds in a plastic bag. Handling the birds in this way will not put you at risk of contracting WNV.

Potentially fatal mosquito-borne viruses were established in Michigan long before the appearance of WNV. Like WNV, these viruses (St. Louis, La Crosse and eastern equine encephalitis) have animal/bird cycles and are considered very low risks to humans. For more specific information on WNV and its current status within the U.S. you can visit Web sites at the Michigan Department of Agriculture (www.michigan.gov) and the Center for Disease Control (www.cdc.gov).

Transmission

The WNV transmission cycle is illustrated in Figure 1. Mosquitoes acquire the virus by feeding on the blood of infected hosts. The virus multiples in mosquito cells and eventually infects the salivary glands. If the mosquito then feeds on an uninfected host, the virus is transmitted. The mosquitoes in the cycle are called disease "vectors" because they move WNV from host to host but are not thought to be affected by it. Note that a mosquito must feed on at least two host individuals to spread the virus. To our knowledge, the mosquito does not pass WNV on to its offspring (called "vertical transmission"). Newly emerged adult mosquitoes must first acquire the virus from an infected host before they can transmit it. Some recent evidence indicates that the virus can be transmitted from human to human via blood transfusions or organ transplants, or breast milk.

We are still learning about which mosquito species serve as vectors. *Culex* mosquitoes are the primary vectors of the virus in birds, but these mosquitoes usually do not bite humans. Other mosquito species that feed on both birds and humans are also probably important in transmission to humans. WNV has been detected in more than 40 mosquito species in the U.S. These "bridge vectors" might include the common nuisance mosquitoes typically abundant in Michigan summers.

As long as the virus is maintained in bird and *Culex* populations, there will be a risk to humans. A key component of the cycle is that *Culex* females overwinter (that is, go into a resting state during the cold months) as adults with viable virus. Therefore, the bird/mosquito cycle begins with adult feeding early in the year and accelerates as birds migrate back into Michigan and mosquito populations build through the summer. In Michigan, we can expect mosquito biting and transmission through September, whether there is a frost during the month or not, and humans will continue to be at risk of exposure to infectious mosquito bites into October, depending on weather conditions.

Mosquito Repellents

Mosquito repellents providing the greatest degree of protection for the longest periods of time are those containing DEET (chemical name: N,N-diethyl-meta-toluamide.) This compound is available in a variety of formulations and concentrations — up to 100 percent active ingredient. It works by interfering with the ability of the adult female mosquito to locate a suitable host. Safety information is available at the EPA's Web site (www.epa.gov/pesticides/citizens/deet.htm), which states: "After completing a comprehensive reassessment of DEET, the EPA concluded that, as long as consumers follow label directions and take proper precautions, insect repellents containing DEET do not present a health concern." Application precautions include keeping DEET away from eyes and mouth and not applying the substance to infants and very young children. DEET can also be effectively applied to clothing, thereby reducing direct skin contact. Citronella candles and repellent coils can be moderately effective for small areas and short-term usage. Plants with alleged repellent properties have not been shown to be effective. Devices such as "bug zappers", traps based on carbon dioxide emission and chemical attractants have not been shown to be effective controls and, paradoxically, could attract more mosquitoes to one's backyard.

Mosquito Control

Potentially, the most effective means of reducing virus transmission is to reduce the vector populations. This requires an understanding of the biology and life cycles of the mosquitoes involved. Larvae of the *Culex* mosquito live in small, organically rich habitats (e.g., storm sewers, discarded tires, clogged

gutters, etc.). Eliminating larval habitats (i.e., standing water) would be a first step in local control. Habitats of the bridge vectors can be roadside ditches, pond margins, flooded areas in fields, etc., and these are not as readily eliminated. Several larvicides have been shown to be effective in these situations. These are applied directly to larval habitats. Microbial insecticides such as those developed from *Bacillus thuringiensis* and *Bacillus sphaericus* strains are available from commercial sources (trade names Vectobac, Vectolex). These concentrated bacterial formulations are most effectively applied in granular or briquet formulations when larvae are in the early stages of development. These biological pesticides are mosquito or insect specific and therefore considered a low hazard for humans and animals.

More traditional insecticides are also available in large pellet or briquet forms that are simply tossed into larval habitats. These include temephos (an organophosphate, trade name Abate) and methoprene (an insect growth regulator hormone mimic, trade name Altosid). An additional control measure is to spread oils or monomolecular films on the surfaces of larval habitats. The oil interferes with the larval breathing structure, called a respiratory siphon, and may also interfere with larval feeding. Although many petroleum products, including kerosene, could serve this function, these are not recommended for obvious reasons. Surface oils and films currently used for mosquito control are designed to minimize adverse effects on other aquatic life. Several counties in Michigan have mosquito control departments, and larvicide applications are conducted on a broad scale (i.e., aerial application to breeding sites or hand application to identified breeding areas throughout a district). Generally speaking, all of the above materials must be purchased by certified applicators.

Control of adult mosquitoes on individual property can also be achieved with judicious use of registered insecticides. Spraying insecticides such as malathion or permethrin on vegetation bordering the yard may reduce local adult numbers and provide a barrier because these areas are daytime resting places. The main vector in the bird-virus cycle prefers tree canopies, however, so insecticide application near ground level would not be effective in eliminating this part of the cycle.

Control of adult mosquitoes on a large scale can be achieved only through spraying insecticides (e.g., malathion or permethrin). Typically, these are applied with ULV (ultralow volume) techniques from a truck-mounted sprayer or smaller backpack units. These techniques apply small quantities of insecticide in minute droplets within a narrow window of time and space. Insecticides typically applied with ULV methods have low toxicity to mammals and have very short residual effects. They are broken down by ultraviolet light and do not persist for more than a day or two. Even so, they are broad-spectrum insecticides and will kill insects and invertebrates other than mosquitoes. Insecticide sprays of this nature should be applied only by professionals, and decisions to spray obviously require community input. We suggest you contact the Michigan Mosquito Control Association (www.mimosq.org) for specific recommendations.

Effective control of adult mosquito populations by bats, birds (e.g., swallows) and other insects (e.g., dragonflies) is largely a myth. Bats have been reported to eat thousands of mosquitoes per night, but this is based only on estimates of what a bat would need to eat to meet its energy demands. Bats feed on many insects, however, and mosquitoes probably make up a very minor portion of their diets. This is also true of birds and dragonflies. If dragonflies were important adult mosquito predators, there would necessarily have to be ponds, etc., in the immediate area because all dragonfly larvae are aquatic. Therefore, to maintain local dragonfly populations, one would also need to maintain potential mosquito breeding sites.

Recommendations

Avoiding infection with WNV is mostly a matter of being informed and aware, and using common sense. Eliminating mosquito populations entirely is an unrealistic proposition, but people can take steps to reduce their contact with mosquitoes and to reduce local mosquito populations.

1. **Personal protection.** Reduce/eliminate local mosquito breeding sites in the immediate vicinity of your home beginning in the spring. Apply personal protection judiciously when your outdoor activities coincide with mosquito activity. We rec-

ommend repellents using DEET as an active ingredient because of its efficacy and safety record. The elderly should be particularly careful when mosquitoes are most active (dusk/night/dawn). Repairing screens and blocking potential entry points into the house are also important precautions.

2. Community-level responses. For broader control, local and state community health organizations should be involved. If large-scale action is deemed necessary, then professional mosquito control representatives should be consulted. Below, we outline plans for a community-level response in an urban area.

First, communities need to control the mosquitoes coming out of street storm sewers and catchbasins. Catchbasins holding water will inevitably have mosquito larvae; they should be inspected for water and then every 30 days in the summer treated with a formulation of *Bacillus sphaericus* (e.g., Vectolex) or methoprene (e.g., Altosid). These formulations are available as granules, pellets and briquets. They are efficacious, low risk and reasonably priced. A trained crew can locate and treat the catchbasins of an entire community within a few days. The drawback of this component is that it ignores other potential mosquito sources, yet it focuses on the most important ones for *Culex* mosquitoes. Some communities may find it desirable to locate other mosquito sources, such as wastewater lagoons, and treat them as well.

Second, communities should control adult mosquitoes in circumscribed green spaces in urban areas, such as cemeteries, parks, golf courses, zoos, vacant lots, college campuses and other locations where crows roost at night in tall trees. The approach involves ultralow volume (ULV) application of synthetic pyrethroid insecticides such as Anvil (containing sumithrin) or Biomist (containing permethrin) from truck-mounted equipment. This approach will specifically target the *Culex* mosquitoes as they attempt to locate and bite crows at night, and will interrupt virus transmission and dampen virus amplification. It not only reduces the sheer number of mosquitoes but also kills the older mosquitoes that are more likely to be infected with the virus. Our studies in Michigan this summer show that the majority of the *Culex* mosquitoes are active in the tree canopy at night and are not at ground level. The drawback of this component is that it ignores residential and commercial areas. Directing these applications into the tree canopies of non-residential green spaces reduces citizens' concerns about spraying near their homes.

The use of anti-larval and anti-adult mosquito pesticides is recommended because of carefully conducted risk analyses and reviews by the EPA, the U.S. military, and the New York city and state departments of health, as well as studies conducted in Michigan. Collectively, this body of knowledge indicates that the anti-adult insecticides (which are man-made analogs of natural pyrethrum, used in the organic farming industry) have acceptably low health and environmental hazards when applied properly. This class of insecticides is used on children to control head lice, on the skin of elderly persons to control scabies, on pets to control fleas, in jackets to protect soldiers from mosquito bites and in bed nets to prevent infants in the tropics from getting malaria. It would not be necessary to conduct expensive health hazard and environmental risk assessment studies before green spaces or catchbasins were treated — such analyses have already been done.

Third, communities should act to control major food sources of crows in urban areas — namely, garbage bags set at curbside and roadkills. Crows have become increasingly urbanized in the past three decades, subsist on man-made food and easily tear open garbage bags to eat the contents. Citizens should secure their garbage in covered containers set at curbside for pickup. Municipal road crews should actively seek out and dispose of road-killed animals that provide food for crows. With these food sources eliminated, urban crow populations will decrease and fewer will be available as reservoirs for WNV.

Finally, elected and employed community officials must accept the challenge of an active WNV surveillance and control program. The information provided above outlines a proactive program of limited scope and acceptably low hazards. None of the components are budget-breakers, yet they still involve taxpayer money, and citizens have a right to expect that their money is used wisely. Community members can be encouraged to participate actively in surveillance. If no virus-positive dead crows occur, the program can be curtailed and funds redirected, but surveillance should continue and the control program activated when positive dead crows are reported.

Additional information can be obtained at these Web sites:

General information on mosquitoes and mosquito control in Michigan: www.mimosq.org

General West Nile virus information: www.cdc.gov/ncidod/dvbid/westnile/resources/wnv-guidlines-apr-2001.pdf

Michigan West Nile virus information: www.michigan.gov/mda and link to West Nile virus

Information on insecticide use and safety for West Nile virus vector control: www.nyc.gov/html/doh/pdf/wnv/fexec.pdf

www.gulflink.osd.mil/library/randrep/pesticides_paper/mr1018.8.ch6.html#note3

www.epa.gov/pesticides/citizens/mosquitojoint.htm

www.epa.gov/pesticides/citizens/pyrethroids4mosquitos.htm

www.epa.gov/pesticides/factsheets/skeeters.htm

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